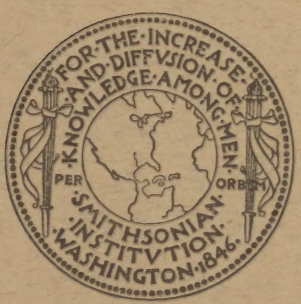
THE MOSQUITO FISH (GAMBUSIA) AND ITS RELATION TO MALARIA

BY

DAVID STARR JORDAN

FROM THE SMITHSONIAN REPORT FOR 1926, PAGES 361-368
(WITH 4 PLATES)



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THE MOSQUITO FISH (GAMBUSIA) AND ITS RELATION TO MALARIA

By David Starr Jordan

[With 4 plates]

One of the most important discoveries of the nineteenth century was that of the nature of malaria, with its kindred diseases, yellow fever, dengue, and the like. It has been found that malaria is not a product of miasma or foul air, as the accepted name of "bad air" would signify. Neither is it "catching" in the ordinary sense of propagation by contact. It is borne from one person to another by the bite of mosquitoes. The big mosquitoes of the North (*Culicita* and the like) may offend by their abundance, their vociferous song, and their vicious bite, but they do not carry disease. The dangerous ones are smaller, less insistent, and with a softer voice, but some of them transmit active and dangerous poisons.

The cause of malaria of all sorts, ague, chills, and fever, "remittent" and "intermittent fever," as well as of the more vicious "Roman fever" and dengue or "break-bone fever," and the most virulent of all, the yellow fever, is the presence in the blood of multitudes of minute, parasitic animals, wormlike in form, which at intervals breed in prodigious numbers, with varied degrees of danger or discomfort. The biting of a man having malarial trouble by a mosquito of certain kinds (*Anopheles*, *Ædes*, and *Stegomiya*) transfers one or dozens of these creatures to its own body, causing it, no doubt, lamentable discomfort. Later the mosquito may bite another person "to take the taste out of his mouth," and in this next victim fever follows, thus passing the malady along from person to person through the agency of the mosquito's body. It is said that in most species only the female bites and that she does so chiefly after drawing blood.

The problem of the cure of malaria rests primarily on our skill in poisoning the malarial parasite with the least damage to their human host. Thus far the most successful method has been the use of salts of quinine. This is extracted from Peruvian bark derived from the tree, *Cinchona calisaya*, and numerous other species of *Cinchona* and *Reinija* and is fatal to all malarial microbes with which it comes in contact. Quinine is not a very wholesome drug as far as man is concerned though used under numerous conditions. The main point is that it kills microbes without killing the patient.

But prevention is always better than cure. The surest way to put an end to malaria ravages is to extirpate the mosquitoes. In rainy regions this is hard to do, but the worst kinds of mosquitoes belong to the Tropics or to regions just north of the Tropic of Cancer. They are often virulent in swamps, but apparently equally so in dry regions in ponds and puddles not connected with jungles. Thus certain districts in the Ukraine, in Anatolia, in Macedonia, in Greece, and in southern Italy have been historically notorious for malarial diseases. The Campagna of Rome, "Five Fingered Sparta," and probably Mycenæ, the original source of Hellenic culture, are classical examples of the undoing of populations by mosquitoes. The fading of "the glory that was Greece," due primarily to her suicidal wars, must have been in large part also the work of mosquitoes. I know personally something of their havoc in Macedonia and I am told that in regions about the Black Sea, Ukrainia, and Anatolia, the plague is still more virulent.

Near Salonika in Macedonia the Turkish authorities built an agricultural school and experimental station near the sea, at the foot of a marshy valley. This was found to be uninhabitable on account of the poisonous mosquitoes.

The work of our Army surgeons, Dr. Walter Reed, Dr. Jesse Lazear, Dr. James Carroll and their associates, in cleaning up fever-stricken Havana, is a classic in medicine. This has been followed up by the drastic purification of Panama, Vera Cruz, Guayaquil, and other poisoned ports, the work of Gen. W. C. Gorgas and others. To get rid of mosquitoes is now one of the most important elements in "preventive medicine" or sanitation.

But how shall this be done? There are three general lines of attack—to get rid of their breeding places, to cover these with oil, or to bring in an enemy which will devour their eggs and young. In this connection I may refer to a plan in Texas to build and protect bat houses, as bats in the night devour mosquitoes as well as other insects. But a colony of bats can operate on a very small scale only, and I need not refer to them further.

Pools and other breeding places can often be drained or filled up with sand or rock. As all mosquitoes lay their masses of eggs in quiet or stagnant water, in which they hatch, a layer of petroleum over the water will smother their larvæ or "wigglers" and will also prevent the winged insect from escaping. But there are many bodies of water in which neither of these methods can be used. In such cases, the mosquito-eating fishes are the best resort. A good many kinds of little fishes will eat mosquito eggs or larvæ when they find them convenient. Sticklebacks, young trout, some minnows, even gold fish do this to some extent. But what is needed is a

kind of fish that makes mosquito killing its chief business, which enters on it with alacrity and which will not and can not harm other more choice kinds of fish. In southeastern Asia is a group known as *Betta*, little perchlike fishes, skillful as mosquito devourers, but quarrelsome and destructive to other small or young fishes.

The desired traits are found in perfection in the "top minnows" or "Gambusinos" of the genus *Gambusia* Poey. Of this genus there are numerous species in warmer parts of America. Most of them belong to coast streams of eastern Mexico. Two of them, very much alike, range through our South Atlantic and Gulf States. One of these, *Gambusia patruelis*, is found from Florida to Texas in sluggish streams of the Gulf States and northward to southern Illinois. Another, *Gambusia holbrooki*, extends from Georgia northward, in lowland streams, swamps, and rice ditches of the South Atlantic States, and ranging to the lake of the Dismal Swamp in Virginia. A third, *Gambusia affinis*, belongs to the Rio Grande region, and is now regarded as distinct from *Gambusia patruelis*, though the structural differences are small, and in their habits and food all three are doubtless alike. In Cuba, such littles fishes are called "Gambusinos," hence their scientific name *Gambusia*. When an angler returns without fish, the Cubans say, he has been "fishing for Gambusinos."

The United States Public Health Service has lately published a valuable series of experiments undertaken about Augusta, Ga., by Samuel F. Hildebrand, of the United States Bureau of Fisheries. This is entitled, "A Study of the Top Minnow (*Gambusia holbrooki*) in Relation to Mosquito Control."

Old travelers may remember that Hawaii, 20 and more years ago was cursed by mosquitoes. In my first visit to the islands (1900), large ones brought from Alaska by whalers in their water tubs, in the days when Hawaii was their chosen winter resort, ruled the islands by day, and a smaller form, probably from California, was heard at night. Neither of these carry malaria, but both were excessively annoying.

Mark Twain, at the old Hawaiian Hotel felt this grievance, and in a characteristic way set out to remedy it. Everyone in Honolulu then slept under a mosquito canopy and each night some of the smaller insects crept through the meshes. Mark waited until all the mosquitoes came in through the netting and then slipped out and slept on the floor.

But even this shrewd device often failed. At last, in 1904, the City of Honolulu (knowing the present writer to be a fish sharp), sent a credit of about $1,500 (of which about $600 was used) asking me to discover and send to the islands a fish that would really eat mosquitoes.

A California student will tackle any problem, and so I sent out Alvin Seale (then a senior at Stanford, now superintendent of the Steinhart Aquarium in San Francisco). He was instructed to go to Louisiana and secure from the bayous three species which might meet the demand. Each of them would eat mosquitoes, but in no case had their efficiency been tested. New Orleans was then once more in the throes of yellow fever, so Seale moved across to Galveston and filled his milk cans with the chosen fishes. Such fishes known as "Top-Minnows," Killifishes, and Cyprinodonts, are all very hardy if properly handled, especially if not handled at all, and very few died on the voyage to Hawaii.

Arrived at Honolulu, each species was tested out in aquarium tanks in drug-store windows, these filled with stagnant water, stocked with mosquito eggs. The largest fishes, *Fundulus grandis*, showed little interest in the matter. They were poured into a pool and have not been noticed since. The next species (*Mollienesia latipinna*) did better. This is a very handsome little fish, with high fins and varied colors, bright blue shades and spots predominating. But it is mainly a vegetable feeder, preferring "frog spittle" (*Confervæ*) to insects, and seemed not likely to be of any value in the task assigned to it. It has become very abundant in the estuaries of Hawaii. It is valued for aquaria and is largely used as bait for the Aku, or Victor-fish (*Katsuwomus*), and other predatory species.

The third set of fishes (*Gambusia patruelis*), rose at once to the occasion, and almost instantly cleared the aquarium of mosquito eggs and wigglers. This, with its twin of further east, *Gambusia holbrooki*, is no doubt the greatest mosquito killer in existence. It has lived and multiplied in all available waters in Hawaii. It swarms in irrigation ditches and in pools in the rice fields. It is so abundant that it is now gathered up in nets, baked and crushed as food for the fishes in the Waikiki Aquarium. It does not migrate to the sea and it does not attack other fishes.

In a recent visit of two months in Honolulu I saw but six mosquitoes, all of them small, no doubt hatched in rain pools, tin pans, or other small bodies of water, which the most assiduous fish can not reach.

From Honolulu the fish has been taken to Formosa by another Stanford student, Dr. Masamitu Oshima, former director of Fisheries in that island, whence specimens have been sent back to me. The fish was then brought over to Manila by another Stanford man, Dr. Albert W. Herre, director of Philippine fisheries, and it has become firmly established in Luzon. Large breeding pools have been established about Manila by Doctor Herre. From the Philippine

streams and marshes about Singapore, Mandalay, and Bangkok either have been stocked by Doctor Herre, or are soon to be so. The fish is now distributed to southern Japan and China, and ultimately will be, I hope, to all the malaria-burdened world.

A native of warm regions, we are not sure how much cold it will stand. Last winter in California, the temperature dropped two or three times to about 30°, but none of the fish seemed to suffer. In early November the old fishes slip to the bottom in mud and weeds to keep warm, but the later born of the flock may be seen near the surface on any of the so-called winter days of central or southern California. The director of the Illinois pond at Carbondale reports that a foot and a half of ice did not kill any of them last winter, as they were all hibernating at the bottom of the pond. In their native regions, snow and ice are unknown, but they do not seem to mind moderate cold if they are allowed to lie still and are not expected to function. As to heat, Hildebrand reports that in nature he has found *Gambusia* in water having a temperature of 102° F. When held in containers they usually die when 100° F. is reached. They feed on flies and mosquitoes by choice, rejecting wasps, beetles, butterflies, or larger insects. I have seen them leap out of the water to seize an incautious fly alighting on the edge of their pond.

These fishes are light greenish brown in color, the fins speckled, but no conspicuous markings anywhere. In the adult there is usually a black shade or bar under the eyes, and the gravid females develop a black area on the side under the skin. The female is 2½ inches long, the male about an inch shorter. About 10 females are born to 1 male. The eggs are hatched in the body of the female, 6 to 10 in a brood, there being 4 or 5 broods between March and September. This is recorded in Georgia, with *Gambusia holbrooki*. In California, with *Gambusia patruelis*, I notice but two or three broods in a season. The young when born are transparent, with big black eyes, and are about a fifth of an inch in length.

A certain number die when first caught and placed in confinement. Those that survive the first three days mostly live on indefinitely. It is therefore well to hold a consignment for a few days before taking them for a long distance. In summer time about 150 can be transferred in July in a 50-pound lard can, and in October as many as 500. In summer time a wet jacket of burlap around a can is desirable, but ice and overaeration are both risky.

Mr. Hildebrand does not discuss the artificial feeding of these fishes. The very young evidently feed on minute or tender algæ, as desmids and *Confervæ*. The adult, in default of mosquitoes, take kindly to *Confervæ*. The *Gambusias* in my own pool are fed on goldfish food. The kind which is made of rice-flour pressed into flat cakes they eat eagerly, especially if cut or torn into very small

pieces. The fact that this floats and can be reached on the surface from below, they seem to appreciate. The goldfish food made from crushed shrimps they will eat also, but as this soon falls to the bottom it is not so well adapted to their habits.

The *Gambusia* is very tenacious of life. It does not, however, endure rough handling, and the gravid females are very sensitive to harsh usage. They should be taken from the water in a dip net, not a seine. According to Mr. Hildebrand "the best container for transferring and shipping *Gambusia*, undoubtedly is the Fearnow fish can, a patented device. Excellent results can be had by the use of lard cans, lard tubs and similar containers. If secondhand vessels are used, they must be thoroughly washed and scalded with hot water." The water in the container should be shallow, forcing the fish to keep near the surface. This need indicates the undesirability of milk cans. When under way the less splashing the better. "The Fearnow can successfully overcomes splashing and is very convenient, for transporting fish over rough roads."

Mr. Hildebrand further adds that it is usually advisable to confine *Gambusia* in the water from which they were caught. If this water is foul, it should not be used. It generally is best when *Gambusia* in confinement are to be transferred from pond water, for example, to water from another source, to mix the waters at first and accomplish the change more or less gradually.

In establishing the mosquito fish in a new region, it is well to prepare a shallow pond some rods in diameter, with a lining of concrete to prevent leakage. So far as my experience in California goes, this should not be over 4 feet in depth. The pond may be stocked in the middle with pond lilies and water plants, not set so densely as to smother the little fishes or to prevent them from readily getting about when hunting down "wigglers." Even *Confervæ* (frog spittle), on which young fishes seem to feed, will help, but the plants need clearing out when too abundant. The sulphate of copper (blue vitriol), sometimes used to clear the water by destroying *Confervæ* and the like, is fatal to *Gambusia*. The little fishes, however, make no objection to sewage in the water, and flourish in the gutters of Vera Cruz and other filthy cities in which open ditches take the place of sewers.

As to the enemies of *Gambusia*, I have noticed but one especially destructive. This is the large water beetle, *Dytiscus*, about an inch long and of a shining brown color. This species entered my pool, and before it could be extirpated, one had killed a mother fish and another a goldfish.

In a small pool in a garden a fungus once appeared, forming a white ring about the eye in individuals attacked. I imagine that bass and similar carnivorous fishes would attack the *Gambusia*, and

that it might fall prey to ducks, coots (mud hens), king-fishers, and other like birds of prey. To what extent these creatures would do mischief I can not say.

The present writer first brought the value of *Gambusia* to public notice in the Scientific American in May, 1926. Parts of that article are repeated here. Since then he has had an extended correspondence with persons interested, in various parts of the world—London, Paris, Berlin, Florence, Rome, Buenos Aires, Salonika, Singapore, Calcutta, and especially with the American Red Cross people, who hope to redeem those parts of Russia most specially cursed. For nowhere in southern Europe, northern Africa, nor western Asia is there any species of fish devoted to the destruction of mosquitoes and their eggs and larvæ. About the Mediterranean and the Black Sea its help is most particularly needed.

I may quote from a personal letter of Dr. L. W. Hackett, of the International Health Board of the Rockefeller Foundation, director of "La Stazione Sperimentale, per la Lotta Antimalarica" at Rome. He writes me of the work in Italy:

Gambusia was first introduced into Spain by Dr. Massimo Sella,[1] director of the antimalaria work, by the help of the American Red Cross. Doctor Grassi, the famous Italian malariologist, had *Gambusia* brought to Italy from Spain. They were imported first to the drainage canals at Ostia and Fiumicino at the mouth of the Tiber and in the four succeeding summers have multiplied prodigiously. This fish seems to have left behind its natural enemies and to be more at home in Italian and Spanish waters than it ever was in America. For one thing, the weaker males, which in America are always found in disproportionately small numbers, here seem to survive and in many places equal the females in number.

The International Health Board of the Rockefeller Foundation has recently established in cooperation with the Italian Government an experimental antimalaria station in Rome with field laboratories in different parts of Italy. This station has made a wide distribution of *Gambusia* in all parts of Italy, in Jugoslavia and in Dalmatia as well. It would therefore be a very simple matter for Mr. (John Henry) House to obtain these fish in Salonika.

These fish, owing to the enormous numbers which develop in ponds and streams are more effective against mosquito larvæ than they were in America. They will penetrate many kinds of horizontal aquatic vegetation, and will do away with from 80 to 90 per cent of *Anopheles* larvæ. There are many types of water, however, both permanent and intermittent, to which they can not adapt themselves and our judgment is that although they are a great help in antimosquito work, conditions are rarely such as to make it unnecessary to do any other kind of antimosquito work. However, as their introduction is inexpensive and their maintenance practically nil, they represent a measure of which practically any community can avail itself in mild climates.

A hopeful pond was established at Tirana, the capital of Albania, and stocked with fishes from Rome. It was washed away by a "cloud burst" and the water all leaked out through its gravel bottom.

[1] Doctor Sella, in a recent valuable report, records the establishment of 59 ponds in Italy, Yugoslavia, Macedonia, Albania, and Palestine.

A letter from Tirana to the Red Cross Courier, thus describes this mischance, unfortunate, though no doubt the fishes will reappear in other pools nearer the sea.

You must know of the *Gambusia*, some kind of a small fish which feeds on green vegetation in ponds garnished with the larvæ of the *Anopheles* mosquito. The strange thing about the fish, according to my information, is its intelligence. It will have its salad, I believe, dressed only with *Anopheles* larvæ. Some American doctor figured it all out.

Well, our school (Tirana) pledged itself to breed *Gambusia* in phalanx. We wrote to Rome of our latest enterprise and requested that the Rockefeller Foundation there be asked to arrange to transport fishes for a breeding pool in Albania.

We had the fish transported to Tirana and during the next hectic two days succeeded in establishing at the farm the first scientifically arranged fish pond in Albania. It was especially designed with cunning weirs to form the habitat of *Gambusia*, except that it had no waterproof bottom.

Water was turned into the new pond, the fish were tenderly removed from the patent Rockefeller tin and that night we went to bed with light hearts; such are the rewards of happy labor, and were we not in the thick of malaria campaign? For my own part I dreamt that I was watching a great *Gambusia*, up on its tail like a kangaroo, chasing some kind of a gaunt *Anopheles* specter all over the salt sea marshes that circle Durazzo.

And then I awoke. It was raining one of these miserable Albanian rains that drop out of a leaden sky and smother the earth with a blanket of water. It continued to rain all day and into the night. The next morning big Kesova Bill from the farm appeared at the school, tragedy written all over his erstwhile cheerful countenance.

It appears that during the afternoon of the day previous he had inspected the pond and the *Gambusia*. The pond was all right. The fish were all right. The next morning early, he had an uneasy feeling that all was not well with our part of the malaria campaign. He went to the pond. Water and fish were gone; not a trace remained. No fish, no water, only bits of shiny white gravel over which they had disported themselves so confidently two days before.

Where did the fish go? Where did the water go? No one knows. We only know that they are gone and another mystery awaits solution. In the meantime we are praying the indulgence of the Rockefeller people in Rome for another consignment. Breeding time comes in the spring so that we have lost nothing and gained much in experience. Up to the present time, however, we can produce only excuses for our part in the malaria campaign. In addition to constructing a fish pond with a water-proof bottom we are also constructing a bomb-proof cellar as a matter of precaution should an expert drop into our midst with queries concerning the precious *Gambusia*.

From Manila I have an account of a home built on the shores of a pond, which the mosquitoes made uninhabitable. When Doctor Herre introduced the *Gambusia* into the water, the situation is reported as having become delightful.

With *Gambusia holbrooki* or *Gambusia patruelis* or both, well established and active in the pools and swamps of Southern Europe and Western Asia, thousands of lives can be saved, millions of others rescued from perennial misery and hundreds of square miles now vacant, restored to industry.

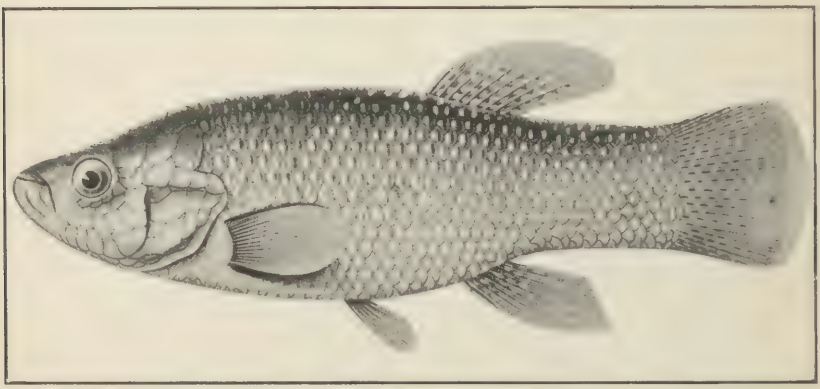
○

1. GAMBUSIA HOLBROOKI, CHARLESTON. AFTER GARMAN

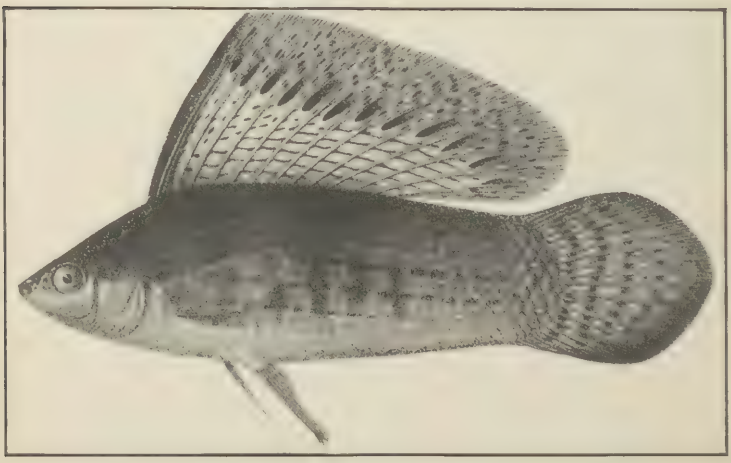
2. GOODEA LUITPOLDI (STEINDACHNER). A VIVIPAROUS FISH FROM LAKE PATZCUARO, MEXICO

Family Pœciliidæ, showing the method in which the young are stowed away after the egg hatch. After Seth E. Meek

1. FOUR-EYED FISH, ANABLEPS DOVII GILL, TEHUANTEPEC, MEXICO



2. FUNDERLUS GRANDIS



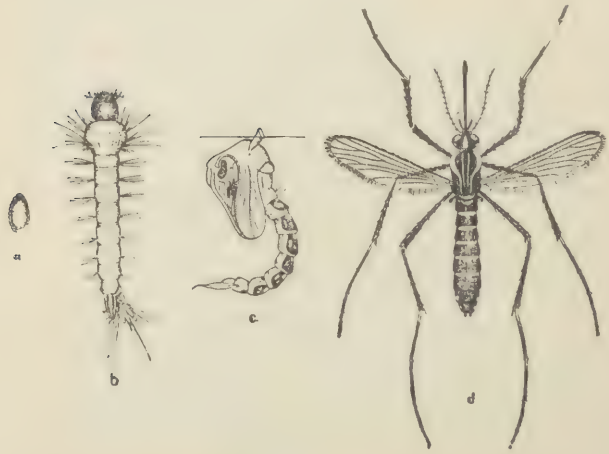
3. MOLLIENESIA LATIPINNA

1. CULISITA INCIDENS. THE BODY OF THIS COMMON MOSQUITO IS HORIZONTAL WHEN BITING, GIVING ASSURANCE THAT IT WILL NOT TRANSMIT FEVER

2. ÆDES SQUAMIGER. A HARMLESS SALT-MARSH MOSQUITO. NO MOSQUITO THAT RESTS HORIZONTALLY WHEN IT BITES IS A BEARER OF MALARIA

1. ANOPHELES MACULIPENNES

This is the American malaria mosquito. It may be easily distinguished because it stands on its head when it bites



2. ÆDES AEGYPTI

This is the well-known yellow-fever mosquito which has caused the death of many millions of human beings